evidence, &c., from which we had to draw our conclusions and results, will be borne in mind, in forming an estimate of the mode in which we have treated this important subject.

We have the honor to be, Mr. President and Gentlemen, your very obedient humble servants,

F. C. Christy, C.E.
F. Acheson, C.E.

Art. XVI.—*On the Influence of the Physical Character of a Country on the Climate; being a Letter to the President, by* R. Brough Smyth, Esq., *Mining Engineer.*

Museum of Natural History, Melbourne.
March 8, 1855.

Sir,

Considerable attention being directed, at this time, to the capabilities of the rivers in the colony of Victoria, in respect of water supply, I have the honour to submit, for your perusal, the following observations:—

I am aware that attempts have been made, very recently, to calculate the probable annual discharge of water from a river by computing the drainage area, the rainfall, the evaporation, &c., but as there are other counteragents, equally worthy of attention, and bearing directly upon the results of such calculations, I propose to offer some remarks, that may, perhaps, arrest the attention of those immediately interested.

My present object is more particularly to inquire how far the physical character, and the geological structure of a country, extend their influence over peculiarities of climate and in what manner they serve to determine the hydrographical features. This connexion, Sir, which I shall seek to establish and enlarge, is, as you are aware, not new to those who have made the science of Geology their study. As I design to apply it, in a practical sense, to the solution of some questions which have been lately brought before the Philosophical Society, I feel that I shall best accomplish this purpose, by divesting it entirely of purely local interest. This increases the difficulties of the subject, which I approach with some reluctance, aware of the many and great sources of error to which all such inquiries are liable; and yet, if conducted with ordinary care, and with impartiality, it cannot fail to place in a new and important point of view, many questions of great public interest; of greater interest here, than in other climates where the hydrographical features are of a different character; and whatever errors may occur, they will be out of all proportion to the useful results of such an inquiry.

Geological Formations of Victoria.—This country may be described as consisting of vast beds of sandstones, shale, and clay slate, members of the Primary Fossiliferous series. These beds are variously contorted, and dipping at angles of 30°, 40°, 60°, and 70°, and they are sometimes vertical. Mr. Selwyn,* the Government Geologist, estimates the thickness of these deposits at 30,000 feet or more, and this is probably very near the truth. These sandstones and clay slates have been upheaved by Plutonic rocks, which are found to occupy comparatively large areas. The hills in the Ovens district, Mount Alexander, Mount William, and the hills in the north-eastern parts of the province, are granitic, and excellently illustrate the character of such rocks. Then, there are plains of basalt, sometimes of great extent, where the subordinate rocks are entirely hidden, or only appear in isolated hills of some height, or where denuding causes have removed the upper basaltic formation.

Basalt is also found filling the valleys, near the rivers, and in such cases the streams have cut a passage between the former rock and the clay slate; as may be seen in some parts of the river Yarra, in the rivers Coliban and Campaspie, at the Deep Creek near Mount Greenock, and in many of the streams in the western part of the Province.

A considerable part of the Great Dividing Range is composed of igneous rocks, and they in like manner form isolated hills in many localities, which sometimes attain a considerable altitude—as Larnè Baramul, Mount Boninyong, Mount

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* "The great longitudinal extent of the auriferous deposits is a fact, not difficult of explanation, when we regard what appears to be the general geological structure of the country, which, in making a section from east to west, or from the Australian Alps to the Pyrenees and Grampians, is found to consist of a succession of steep hills, ranges, and gulleys, composed of an enormous thickness (30,000 feet, or more) of upheaved and contorted palæozoic and older strata, intercepted by great masses of granitic and other apparently non-auriferous plutonic rocks, with extensive intervening tracts of recent igneous or volcanic rocks, forming plains and table lands, also non-auriferous, but, in all probability, often resting on and concealing auriferous deposits."—*See page* 10, *Geological Surveyor's Report*, 1854.

Warreneep, Mount Greenock, Mount Macedon, &c. Of other formations—the Carboniferous and the Tertiary, it may be proper to mention that the former is found to extend over very limited areas, while the latter is constantly met with, but rarely of considerable thickness.

The secondary series is supposed to be wholly wanting, but our knowledge of the geology of the province is insufficient to determine this with accuracy. I beg to ask inspection of section No. 1, which is intended to show the structure of the country, and the general arrangement of the strata. How far it tends to explain the phenomenon of river beds without rivers, and the absence of the numerous springs which are found in countries of a different character, I shall presently proceed to explain.

General Configuration.—The physical character of the country is low and level.

The Great Dividing Range which separates the tributaries of the river Murray from the waters flowing southward, is elevated about two thousand feet above the level of the sea. There are hills much higher than the general elevation of the chain—as Mount William, 5,300 feet or more, in the western district, and in the north-eastern part of the country the Australian Alps reach a height of 7,000 feet above the sea, according to the observations of Mr. Tyers and others who have surveyed the district.

There are a number of spurs at right angles to the Great Range, the culminating points of which are from 2,000 to 3,000 feet in height. These minor spurs are flanked by steep narrow ranges, often densely timbered with stringy bark (*Eucalyptus Fabrorum*), or covered with dense scrub.

When we examine the vast extent of country lying between the Dividing Range and the river Murray, we notice, as a remarkable feature, the inconsiderable height of the ranges, and the continual recurrence of intervening plains, many of which are twenty and thirty miles in extent. The Wimmera district, towards the west, is very low and flat. From the Glenelg northwards there is a succession of sandy plains, covered with Mallee scrub (*Eucalyptus dumosa*), which alone must exercise a powerful influence on our climate.

The country south of the Dividing Range is broken into hills, ranging from 500 to 1,500 feet in height. And, again, there are plains of large areas, differing but slightly from those to the northward. This is the proper place to remark that the country south and east of the Great Range contains a greater number of streams than that to the north, and, probably the waters flowing southward have an aggregate volume equal to many times that of the southern tributaries of the Murray.

From this rapid glance at the main features of the country, we are led to infer that very little practical importance can attach to meteorological observations limited to one locality. For example, the fall of rain in Melbourne will be greater than that in the northern part of the Wimmera district. Again, that of the Ovens district must be different to either of these—judging alone from the local peculiarities of configuration. Indeed it would be difficult to calculate the rainfall in any given district, even to a remote approximation, by data resting on observations in a place situated as Melbourne is.

As the above may seem to be arbitrary opinions, I will at once advert to the more obvious causes which influence the climate of a country.

It is impossible, under existing circumstances, to confine my observations to Victoria, since we are possessed of only a small amount of information respecting climatic variations in inland districts. Authenticated cases of variation in other countries, however, can teach us important lessons.

*Causes of Differences in Climate.** — The climate of a country, its coldness or warmth, the degree of moisture or dryness in the atmosphere, is not dependent altogether upon its distance from the equator, but is modified, nay, indeed, sometimes entirely altered, by other lands in its neighbourhood, by its insular position, or by its proximity to seas of great depth. Again, its general configuration—its systems of hills and valleys, produce local effects not less appreciable than the former.

There are lands in the southern latitudes, in the same parallel as the north of Scotland, where the line of perpetual snow descends to the level of the sea; and, as an illustration of the changes produced by local causes, I may mention the great difference between the climate of Victoria and that of the northern part of New Zealand.†

The peculiarities in the climate of Australia are owing

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* Those who may be desirous to obtain the best information on this subject would do well to consult Lyell's "Principles of Geology," chap. vii. p. 92, also Humboldt on Isothermal Lines, there quoted.

† During the summer months, in New Zealand, the temperature is generally about 70°, and I am not aware that it is ever above 80°. In winter it varies from 42° to 52°.

rather to distinct characters of geological structure and configuration than to unmodified solar influence. First, with regard to configuration: let us suppose a complete change in the whole of the features of the country. If, instead of the Great Dividing Range, there were a chain of mountains extending from Cape Otway northwards for 500 or 700 miles, with an altitude of 14,000 or 16,000 feet, which is far above the line of perpetual snow in these latitudes, as they are circumstanced, we should have corresponding alterations in the course and extent of the rivers, some of which might, in the discharge of their waters, rival the lesser streams of Russia or America. The lower currents of air, flowing from the south, highly charged with moisture, would be condensed as they approached the snow-clad heights, and copious showers of rain would fall at all seasons of the year. Hot winds would be unknown. In winter we should have ice on the rivers very near the level of the sea. The results of such a change in the features of the country would extend to the neighbouring islands, and the snowy height of Mount Erebus, with the vast extent of land lying around the Antarctic circle might not be unaffected.*

But let us suppose another change, equally great, of a different character. I have previously described this country as being low and level, with extensive plains and chains of hills of inconsiderable height. By a modification of the formative causes producing such results, the whole extent of Victoria might have been raised gradually and evenly to the present elevation of its plains. Instead of the contorted shales and sandstones, and the protruding Plutonic rocks, we we might have had a series of perfectly horizontal strata.† Instead of the gulleys and ranges, the diversity of hill and plain, the result of this would be a level tract of sandy waste, without one hill to break the dreary monotony of the outline. The present rivers and creeks would be replaced by swamps and lakes of fresh and brackish, and salt water, fully exposed to the intense solar heat of these latitudes. Vegetation not

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* It is, perhaps, necessary to state, that the effect here spoken of would tend to moderate the intense cold of the Antartic regions. Very high lands, in Australia, would radiate solar heat over an immense space, while high lands much farther south would lower the temperature very sensibly.

† This is not a violent supposition. The Silurian strata in Russia are invariably horizontal. Sir R. I. Murchison has ably explained the geological structure of that vast country, and he particularly mentions the recurrence of *plains of palæozoic formations*—the strata being horizontal.—See Murchison's Siluria, pp. 16, 19, 322, 323.

very dissimilar to that which marks the era of the later Coal formation would flourish luxuriantly, affording sustenance to tribes of animals suited to such conditions of life.

It is far from my present purpose to enter largely into this branch of the subject; it is only necessary to show how materially configuration regulates the intensity of heat and cold; how a chain of lofty hills may serve as reservoirs of congealed waters, whence rivers are supplied unceasingly; how low level plains, by favouring evaporation, and yet preventing the formation of rainclouds over their surface, either become arid and desolate wastes, or swampy jungles. This is not only true of continents and large islands, but in lesser proportion is known to influence districts of small area. A lofty hill sometimes makes a perceptible difference in the rainfall in its neighbourhood; a plain of a few miles in extent is sufficient to give a distinctive character to the climate within its limits. A difference in the superficial features of a country will not, however, always explain vicissitudes of climate over limited areas. The rainfall, more especially, is largely affected by the direction of the winds. I am anxious to show the superiority of not one particular cause, but rather to recognise them all. Perhaps the best argument I can use is to refer briefly to the almost inexplicable variations of the rainfall in places very near to each other.

Instances of Variations in the Rainfall.—The mean fall of rain for the whole of England is stated to be thirty-six inches, but near London there is a fall of twenty-three inches, and in Cumberland sixty.* The unequal fall of rain in Scotland is also remarkable; the average in Glasgow is rather more than twenty-nine inches, in Edinburgh it is twenty-three; and this within a distance of forty miles! In the south-west of Ireland the rainfall is forty-two inches, in Armagh it is about twenty-two.

The inequalities of climate being so palpably influenced by such a variety of causes, we ought to reject every calculation that is not based on actual observations within the locality, to which such observations have reference.

The Mean Annual Temperature also presents great differences in different localities, and in countries within the same parallels of latitude. As an instance of this I may mention the mean temperature of Switzerland, viz., 47°, which

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* Sir Charles Lyell mentions the following variations:—"At Whitehaven, in Cumberland, there fell, in 1849, 32 inches; while the quantity of rain in Borrowdale, near Keswick, (only 15 miles to the westward,) was no less than 142

singularly contrasts with its geographical position, and is undoubtedly very much owing to the superficial features of the country.

Evaporation.—The amount of evaporation from lakes and running streams has not received that attention from men of science to which it is justly entitled, and the consequence is an exaggerated estimate of the amount of evaporation in warm climates, amongst those whose attention has not been specially directed to its consideration. It may not be out of place here to mention briefly the conditions which are favourable to evaporation, and to show how clearly dependent is this force upon all other atmospheric phenomena, being in itself merely the result of secondary causes, governed by the geographical position of the country, and its configuration.

In the first place, it must be remembered that evaporation is dependent on three very uncertain conditions of the atmosphere—namely, the degree of saturation, the temperature, and the force of the winds. The climate of Victoria, during the summer months, is very warm—the thermometer not unfrequently indicating 100° in the shade—and if the wind is from the north, the dew point oftentimes falls below 35°.* Such a condition of the atmosphere is most favourable to

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inches![a] In like manner, in India, Colonel Sykes found, by observations made in 1847 and 1848, that in places situated between 17° and 18° N. lat., on a line drawn across the western Ghauts, in the Deccan, the fall of rain varied from 21 to 219 inches.[b] The average in Bengal is probably below 80 inches, yet Dr. G. Hooker witnessed at Churraponjee, in 1850, a fall of 30 inches in 24 hours; and in the same place, during a residence of six months (from June to November), a fall of 530 inches!"—*Principles of Geology*, p. 200. Sir R. I. Murchison, in his address at the anniversary meeting of the Royal Geographical Society, 24th May, 1852, also gives some curious information on this point. He says, "My friend, Professor Oldham, in writing to me from Churra Poonjee, in the Khassya Hills, north of Calcutta, states that the rainfall is there about 600 inches, or $8\frac{1}{2}$ fathoms per annum; 550 inches of which descend in the six rainy months, commencing in May; and that in one day he measured a fall of 25·5 inches." . . . . "The annual amount of rain at Alexandria stands in contrast to that which I have just mentioned as occurring in places in India, the quantity at the former being only $7\frac{1}{2}$ inches. This quantity, indeed, might be expected to be small, from our knowledge of the fact that, three or four degrees to the south, the country is nearly rainless."

* These figures, however startling, are not overstated. On Sunday, December 11th, 1854, at $11\frac{1}{2}$ A.M., the thermometer indicated a temperature of 99°, and the dew-point fell to 35°; the wind, during that state of the atmosphere, blowing in strong gusts from the north. On December 13th, at 4 P.M., the

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[a] Miller, Phil. Trans. 1851, p. 155. [b] Phil. Trans. 1850, p. 354.

evaporation; but it happens that north winds are the exceptional and not the prevailing winds. When we have south winds, or winds west or east of south, the dew point is commonly much higher; and though the daily mean temperature may yet be very high, the conditions for rapid evaporation do not exist. Unquestionably, as compared with many other climates, evaporation is very rapid in this country; but I am justified in stating, that the amount of evaporation during the seven months commencing in April bears no proportion to the rapid evaporation during the other five months; and this is owing to the low prevailing temperature, and the moist condition of the atmosphere. During the rainy season the daily mean temperature is very low, the air is laden with moisture, and, excepting a few chance days, when a dry north wind prevails, evaporation progresses very slowly. With a temperature of 57° the dew-point is not unfrequently 48° or 49°, and even higher; and should the wind come from the west or south-west it sometimes happens that we have an atmosphere almost completely saturated. With the temperature and dew point as above stated, the daily evaporation is seldom more than 8-100 of an inch per diem, under a stiff breeze. In the absence of figures, derived from daily observations, extending over a period of twelve months, I cannot even venture to hint at the amount of evaporation in Melbourne; and how much more should we hesitate to express any opinion as to the amount of evaporation in far distant places, under often changing conditions? It is impossible, I repeat, to calculate the amount of evaporation from tables of temperatures during the several months of the year, unless we are also informed as to the daily hygrometric condition of the atmosphere, and the force of the wind; and even with that information, the result would be the mere expression of an opinion, valueless as a matter of fact. I am the more anxious to enforce these facts, as, unless they are borne in mind, much valuable time may be mispent in calculations and discussions, not merely useless but dangerous to the true interests of science.

Effects of Different Geological Formations.—I will now

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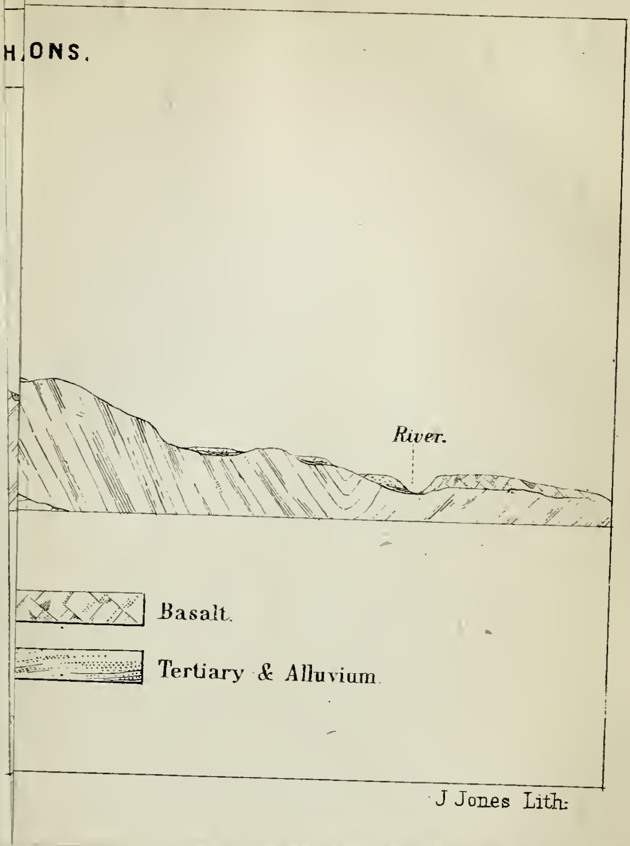
wind had changed to south, and the thermometer fell to 65°, while the dew-point was 46°. On January 29th of this year, at 11½ A.M. the thermometer stood at 109°, and the dew-point at 41°, the wind being from the north; and in the afternoon of that day, at 4 o'clock, the thermometer indicated a temperature of 78°, the dew-point being 58°; the wind, meanwhile, having changed to south. I have drawn these facts from the Meteorological Journal of Dr. Davey, the Assay Master.



The numerous gulleys are, however, almost invariably covered with a thin stratum of porous sandy clay and gravel, with a pretty strong clay substratum.

Even if the ridges of paleozoic rocks were less steep, and better clad with soil, it is evident if they absorbed much of the rainfall, that it would be conveyed to great depths beneath the surface, and could not again appear as springs except under very peculiar circumstances.

The granite rocks may retain small supplies of water, which slowly percolating through the close seams of such a rock, will reappear in small patches of swamp or in springs, but these latter are seldom found of large volume.

Streams of water which are seen to issue from granite rocks, are usually traceable to some swamp or morass in the

No. 1

SKETCH OF A SECTION, SHEWING THE GENERAL CHARACTER OF THE GEOLOGICAL FORMATIONS AND THEIR USUAL RELATIVE POSITIONS.

Victoria, — —Australia.

Granite.

Sandstone & Clay slate *(Paleozoic)*

Basalt

Tertiary & Alluvium

Surveyor Generals Office, Melbourne, June 1855.

Drawn by R. Brough Smyth Mining Engineer.

J Jones Lith:

proceed to consider in what manner geological formations may take the place of other physical characters in modifying a climate. These act, either by storing water in subterranean lakes, and in loose sandy strata, or by permitting the storm waters to flow rapidly and at once to the river basins, and thence to the sea. Under the former of these conditions we have permanent and abundant springs and well filled river basins; under the latter, feeble springs, generally arid summers, and a deficiency of river currents.

In this case I shall confine my illustrations as much as possible to Victoria; but, in attributing all due importance to geological structure, we must not forget that it is only one of the causes formerly adverted to—not the most important in the extent of its results—and chiefly worthy of especial notice, because it immediately concerns man in his daily wants and pursuits.

It is necessary for me to refer you again to section No. 1, which very fairly exhibits the geology of the greater part of Victoria. It will be seen on reference thereto how the rivers of this country are supplied with water.

The paleozoic rocks upheaved by the granite are highly inclined or vertical. The newer tertiary formations and alluvium constantly occur. These are shown in the section, reposing in the valleys, forming the beds of numerous creeks, and separated by steep narrow ranges of clay slate and sandstone.

It is manifest that the storm waters, received on a surface of this kind, must be quickly conveyed to the river beds, since the higher lands are almost destitute of soil. I have seen miles of schistose rocks and granite, where the tops and sides of the ridges presented at every turn the outcrop of the rocks.

The numerous gulleys are, however, almost invariably covered with a thin stratum of porous sandy clay and gravel, with a pretty strong clay substratum.

Even if the ridges of paleozoic rocks were less steep, and better clad with soil, it is evident if they absorbed much of the rainfall, that it would be conveyed to great depths beneath the surface, and could not again appear as springs except under very peculiar circumstances.

The granite rocks may retain small supplies of water, which slowly percolating through the close seams of such a rock, will reappear in small patches of swamp or in springs, but these latter are seldom found of large volume.

Streams of water which are seen to issue from granite rocks, are usually traceable to some swamp or morass in the neighbourhood, and on the surface, as caves or great hollows are rare in the crystalline rocks, and when they do occur, are of small dimensions.

The strata which absorb the largest per centage of storm waters, in proportion to their extent, are clearly those beds of sand and quartz gravel which form the beds of the creeks. Perhaps the most satisfactory evidence of this is to be found in the gold fields, where there are comparatively extensive valleys of quartz gravel, sand, and clay. In winter these form the beds of deep and rapid streams, and it is not unusual at that season to walk across a deep dry gulley one day, and the next to find a current of water some yards in width. The water ceases to flow however very soon after the rain has passed, and in some places, the labors of the gold miner, even in winter, are occasionally obstructed by the absence of a sufficient current. In summer the course of these streams is marked by a succession of small ponds and sedgy swamps; and it is worthy of remark that the ponds are not strictly in the alluvium, but appear where the tilted edges of the slate form a barrier, transverse to the valley, as shown in section No. 2. A question arises here of some importance to the present inquiry,—what can be offered in explanation of the seeming anomoly, the impermeability of the titled clay-slate rocks? All our experience in this colony shows that there are natural basins in these rocks, where very little of the contained water is absorbed. I think the lithological character of these strata is sufficient to explain the fact. These ponds are found where the beds are composed of fine clay and mud, and are so little altered, that they weather into a plastic mass; and when this fills the interstices and joints of the rocks, or covers the extent of the basin to the depth of three or four, or several feet, it will effectually prevent the percolation of water. This of course can only take place where the clay and mud is deposited slowly, and cannot be held to render these rocks impermeable where they rise in steep ridges.

In sinking a shaft through the tertiary beds shown in section No. 2, water is invariably found within a few feet of the subordinate rock. We have abundant proof, however, that the supply is limited, and that strictly according to the extent of the basin, which is sufficient to show that very little water is derived from the neighbouring ridges. If we examine a number of shafts in one of these valleys, commencing at the top of a gulley and going gradually downwards, we observe that the "wet sinking" is always towards the outlet of the basin; and though the surface, even there, may be dry, and

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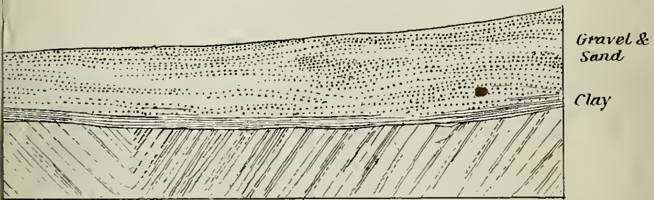
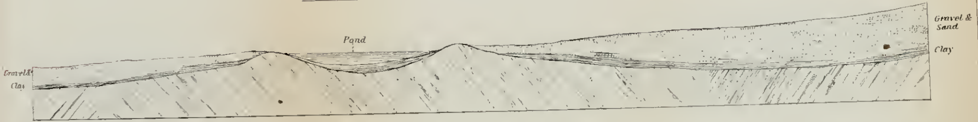


Alluvium.

Drawn by R. Brough Smyth Mining Engineer.

N° 2

Longitudinal Section of a Valley shewing the position of the ALLUVIUM IN RELATION TO THE SANOSTONE & CLAYSLATE ROCKS.



Inclined Sandstone & Clay slate
(Paleozoic)

Alluvium

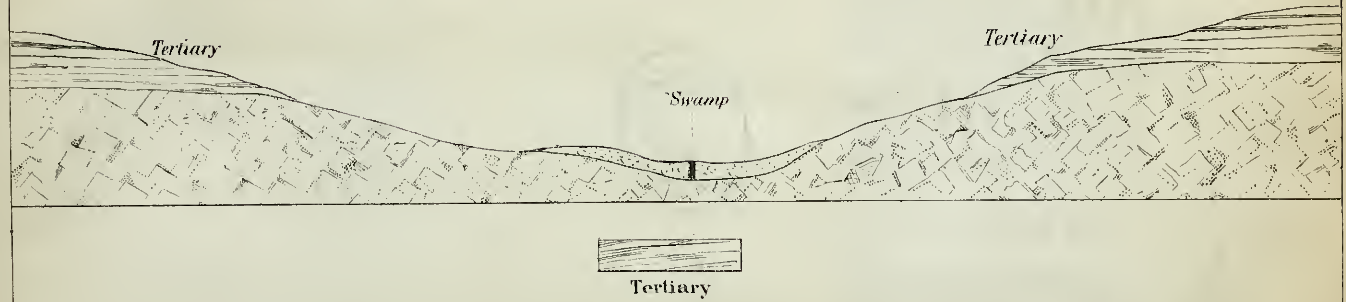
Lithographed at the Surveyor General's Office by J. Jones

Melbourne June, 1855.

Drawn by R. Brough Smyth Mining Engineer.

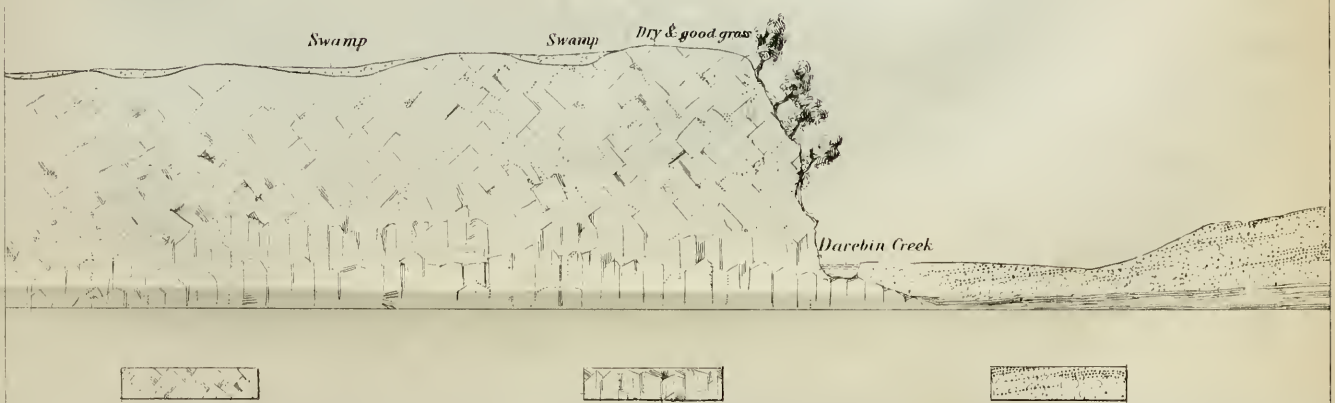
No. 4

SECTION ACROSS THE BASALTIC HILLS NEAR MELBOURNE



N° 3

SECTION ACROSS THE DAREBIN CREEK



Lithographed at the Surveyor General's Office Melbourne June 1855

BY J. JONES.

Surveyed & Drawn by R Brough Smyth . Mining Engineer

N° 4

the grass withered, the quantity of water retained in the gravel and sand is frequently considerable. This water undoubtedly flows very slowly and gradually to the rivers.

With regard to the storm waters which fall on the plains, it is necessary to mention, in the first instance, that the rainfall will be less, on the average, than that received on the higher lands, even under the most favourable circumstances, unless the plain be of very small area indeed. Notwithstanding, a considerable quantity must fall during the year, on plains south of the Dividing Range, and it is necessary to inquire whether it reaches the river beds in the usual manner, or is wholly evaporated, or is absorbed by the soil.

Section No. 3, drawn across the Darebin Creek, represents the edge of a plain of basalt, ending in a steep cliff. In the rainy season the surface of this plain is very wet, and indeed might be called a swamp. The soil is a loose black mould, with a substratum of yellowish white clay; the depth of which varies, being usually from one foot to ten feet. On examining one of the quarries in that neighbourhood, I observed that the spaces between the blocks of basalt were completely filled with this clay, which in short, is due to the decomposition of the rock, and is exactly what we might expect. Taking this circumstance into consideration, we may conclude that a very small per centage of the rainfall will permeate such a stratum, and that its loss may be accounted for by evaporation, and by decomposition.* When we consider the character of the rock, its close compact structure, and the absence of large hollows, we perceive at once, that we must not look there for strong or permanent springs. It is true that feeble springs issue from this rock, highly impregnated with iron, but they are usually in situations where the basalt is decayed, or where the shrinkage cracks are numerous and close together.† In addition to this rock being unfavourable to absorption, it has the

* A relatively small proportion of the rainfall is always decomposed, and the elements form plants—and, of course, that cannot again appear as water. It would be curious to estimate the probable quantity thus lost, in the borders of a reedy swamp, for instance, for comparison; but in an inquiry of this kind it is only necessary to consider what is lost by absorption, evaporation, &c.

† This may seem at variance with the experience of many:—for instance, the high ranges whence the Yarra River takes its rise, are composed of basaltic and other igneous rocks; and many small streams descend from these heights, which are permanent, so far as they flow over impervious strata. This may be due to the dense vegetation covering these hills, which, in a state of semi-decomposition, will retain moisture. I have had some conversations with Mr. Hodgkinson, the District Surveyor, and with Mr. Daintree, the associate of Mr. Selwyn in the geological survey, and the information which those gentlemen have so generously afforded, has led me to take this view of the question.